Atmospheric Profiles, Clouds, and the Evolution of Sea Ice Cover in the Beaufort and Chukchi Seas Atmospheric Observations and Modeling as Part of the Seasonal Ice Zone Reconnaissance Surveys

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LONG-TERM GOALS

The long-term goal of this project is to examine the role of sea ice and atmospheric interactions in the retreat of the Arctic seasonal ice zone (SIZ). As sea ice retreats further, changes in lower atmospheric temperature, humidity, winds, and clouds are likely to result from changed sea ice concentrations and ocean temperatures. These changes in turn will affect the evolution of the SIZ. An appropriate representation of this feedback loop in models is critical if we want to advance prediction skill in the SIZ.

OBJECTIVES

To achieve our goals we will conduct a combination of targeted measurements and modeling experiments as part of the atmospheric component of the Seasonal Ice Zone Reconnaissance Survey project (SIZRS). We will

- Determine the role of changing atmospheric properties in modifying the evolution of the SIZ in the Beaufort and Chukchi Seas from spring through fall.

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- Determine how changes in sea ice and sea surface conditions in the SIZ affect changes in cloud properties and cover.
- Determine the role additional atmospheric profile observations may play in improving the quality of weather forecasts and ice predictions for the SIZ of the Beaufort and Chukchi Seas.
- Adapt a low cost, expendable, air-deployed micro-aircraft to obtain temperature and humidity profiles and cloud top and base heights

APPROACH

To achieve these long-term objectives we will conduct observation and model experiments. The SIZRS project is an integrated observation and modeling program aimed at understanding the interplay of atmosphere, ice, and ocean in the SIZ of the Beaufort and Chukchi seas (BCSIZ). It will take advantage of routine Coast Guard C-130 domain awareness missions that take place at two-weekly intervals from March through November. As part of the atmospheric observation component of SIZRS, this project will deploy dropsondes during SIZRS flights planned at least monthly from April through October to obtain atmospheric profiles of temperature, humidity, and winds. Cloud top heights will be retrieved using infrared imagers and LIDAR deployed aboard the SIZRS aircraft by other SIZRS projects. Sea surface temperatures, ice concentrations, and floe size distributions will be measured by other components of the SIZRS project as well. Our atmospheric observations will be examined in the context of varying surface conditions (sea ice concentration, ice thickness, and SST) to increase our understanding of atmosphere-ice-ocean interactions and to initialize, validate, and improve our meso-scale atmospheric model. Seasonally changing surface conditions are expected to provide a present day analog for expected future ice retreat. Dropsonde observations will be transmitted to forecast centers for potential assimilation into analyses and forecast products. In addition, we will contribute to technology development by adapting and deploying a new generation of truly expendable (<$700) micro-aerial vehicles (Data Hawk and SmartSonde) designed to obtain detailed high-vertical-resolution temperature, humidity and wind profiles and cloud layering information that cannot be obtained with traditional dropsondes. Our vision is that these vehicles will deliver new, inexpensive measurement capabilities for research and operational purposes in the data sparse region of the BCSIZ as well as other regions of the globe. Ron Lindsay (UW) contributes WRF modeling expertise, Jinlun Zhang (UW) conducts sea ice model experiments. Dale Lawrence and Jim Maslank (CU) contribute to AUV expertise.

WORK COMPLETED

Observations:

- We identified and purchased a drop-sonde system from Meteo-Modem. The system is a modified radio-sonde system with low-cost expendable probes.
- We identified a method for launching drop-sondes from a Coast Guard C-130 that does not have a dedicated launch mechansims for deploying drop sondes. An adaptor that mates to the C-130 flare tubes, based on a design in use by the US-Air Force, was manufactured and delivered to the Coast Guard Air force base in Kodiak. AK.

Figure 1. Flare Tube adaptor designed to convert a C-130 flare-tube into a device that allows deployment of drop sondes and Sonobuoy Type -A devices.

- We prepared documentation for the Aircraft Configuration Control Board (ACCB) to obtain approval for deploying drop-sondes during ADA flights. These documents are currently under review and we expect permissions to begin deployment of drop-sondes in October 2012. Progress on this and deployment of drop-sondes has been delayed because of staff-changes at the Kodiak, Coast Guard base.
- We identified an alternate source of atmospheric data for model development and validation from a NOAA air sampling program that is independently conducted onboard the ADA flights. We are currently determining if upper air temperature and humidity information from this program can be used to validate WRF experiment output.

Modeling:

- We set up the atmospheric modeling framework using the Polar Weather Research and Forecast (Polar -WRF) model for the SIZRS domain (Fig 3a).
- We conducted an initial set of experiments using alternating lower boundary conditions to assess the impact of changed sea ice conditions on the atmosphere.Two experiments were conducted. In the first experiment the lower boundary was specified by satellite-observed SST and sea ice thickness from the Panarctic Ice Ocean Modeling and Assimilation System (PIOMAS). In the second experiment, the lower boundary properties (SST and sea ice thickness) were replaced with median conditions obtained from PIOMAS over the period 1979-2011. Integrations were performed from May 15 through Aug-30 2012 to allow comparison with other SIZRS observations and other validation data sources.
- We examined the quality of the lower boundary sea ice thickness data provided by PIOMAS through comparisons with newly available CryoSAT II data.
- We compared SIZRS-WRF model output with surface air temperature information from AXIB and UpTempO research programs which are collaborative projects in the SIZRS program.

Advanced Observation Plaftorms (DataHawk, SmartSonde)

- An update of the SmartSonde design that can fit into an A-size sonobuoy canister and launched from the C-130 via the flaretube adaptor has been developed, constructed, and test flown (a more detailed report is submitted separately).

RESULTS

SST and Surface Air temperature variability from Observations and Models

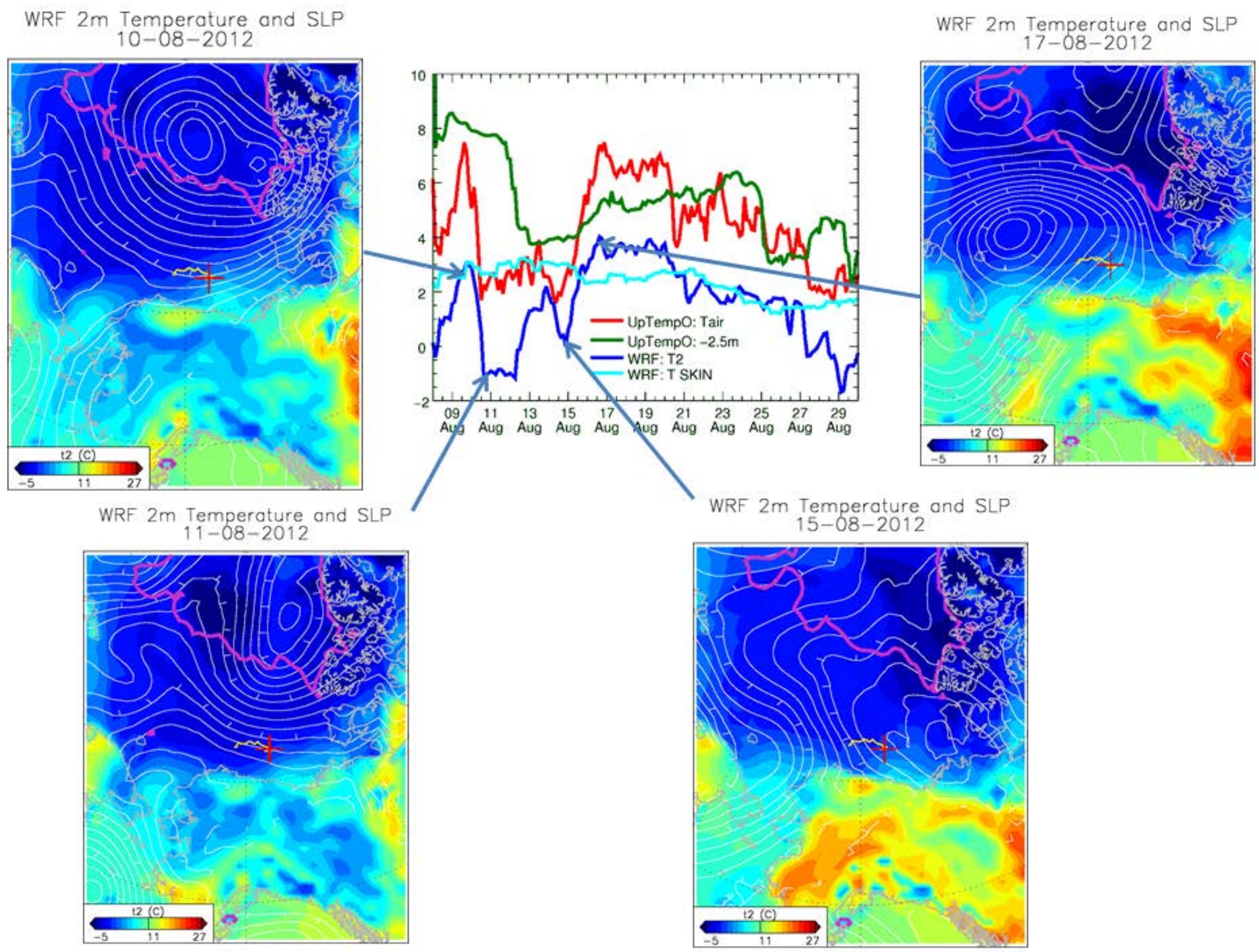

Figure 2 Time series of observed and modeled sea surface and air temperatures from an UpTempO buoy deployed in the SIZRS region. WRF temperatures are derived from a run in which the lower boundary was specified using PIOMAS sea ice thickness. Satellite-retrieved SST is assimilated into the PIOMAS run and used as a lower boundary for the WRF run as well. The ice edge position is shown in pink colors. The UpTempO buoy drift is in yellow and the location of the buoy at the model time is marked with a red cross.

Results from comparisons with in-situ observations (Fig 2 and Fig 3) show that the SIZRS WRF has substantial skill in modeling the variability of surface air temperature in the SIZRS region. Observed and modeled surface air temperatures are well correlated. However, modeled surface air temperatures

are biased low relative to the observations. Comparison of observed ocean temperatures at 2.5m depth (used as a proxy for SST here) show that those are substantially warmer than the satellite retrieved SSTs which are used to specify the lower boundary condition in the WRF runs. This low bias in the satellite retrieved SSTs appears to be responsible for the cold bias in the SIZRS-WRF surface air temperatures. The low bias of standard satellite-retrieved SST products at high latitudes is apparent through comparison with several other buoys deployed within the SIZRS region as part of the IABP program (Fig 3).

Though variability in surface air temperatures is in part controlled by the specified SSTs, the example shown in Fig 2 shows that the advection of air from different directions can significantly modify the SST –surface air temperature relationship. The sequence of surface air temperature and surface pressure level maps shows that temperatures on Aug 10 are under influence of westerly flow and relatively warm. On August 11, in the wake of a passing low, the buoy location is under the influence of northerly flow, as cold air is being advected over the buoy location. Subsequent warming occurs when the air flow becomes southerly with warm air being advected from the warm land.

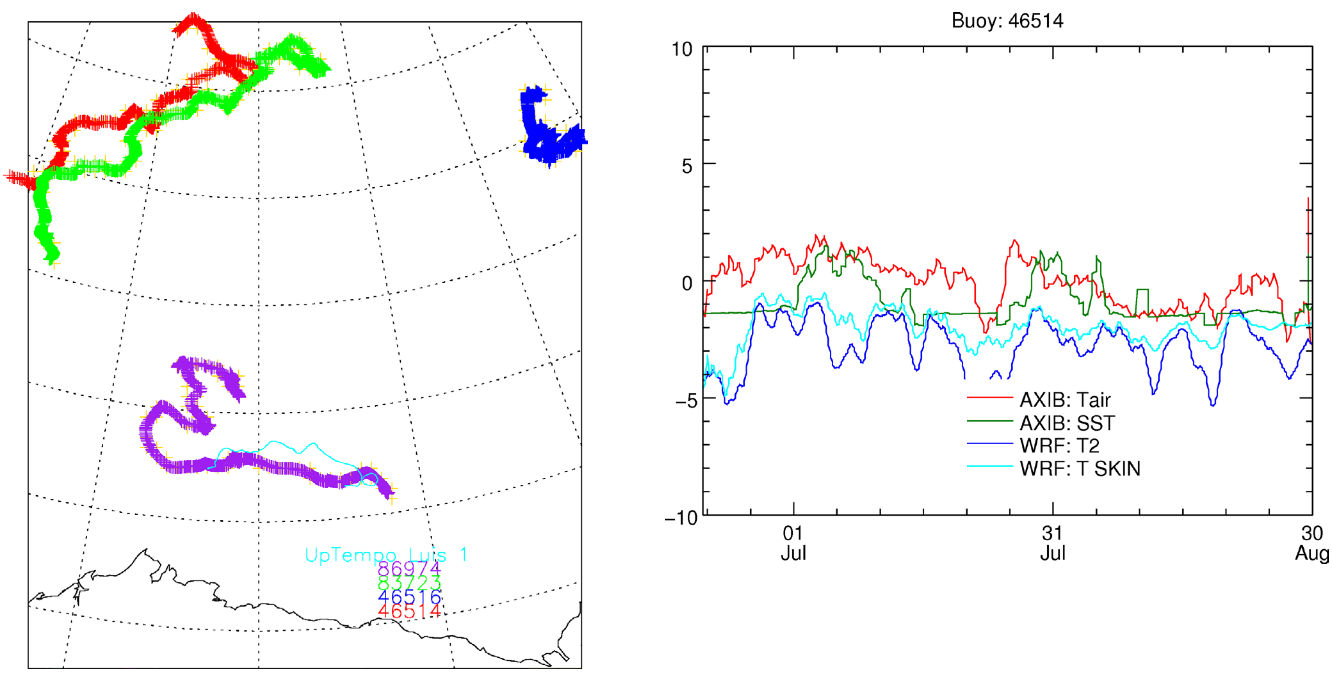

Figure 3 a) Locations of AXIB and UpTempO floats between May 15 and August 30 2012 in the SIZRS domain and b) time series of SST, Surface Air temperature from AXIB buoy no 46514 and corresponding WRF model Surface Air temperature (2m) and surface skin temperature. Though modeled and observed air temperatures are generally well correlated, a low bias is apparent. This low bias, in addition to notable spurious variability in the satellite-retrieved SSTs, appears to be responsible for differences between modeled and observed surface air temperatures.

Impact of sea ice variability on Atmospheric Properties

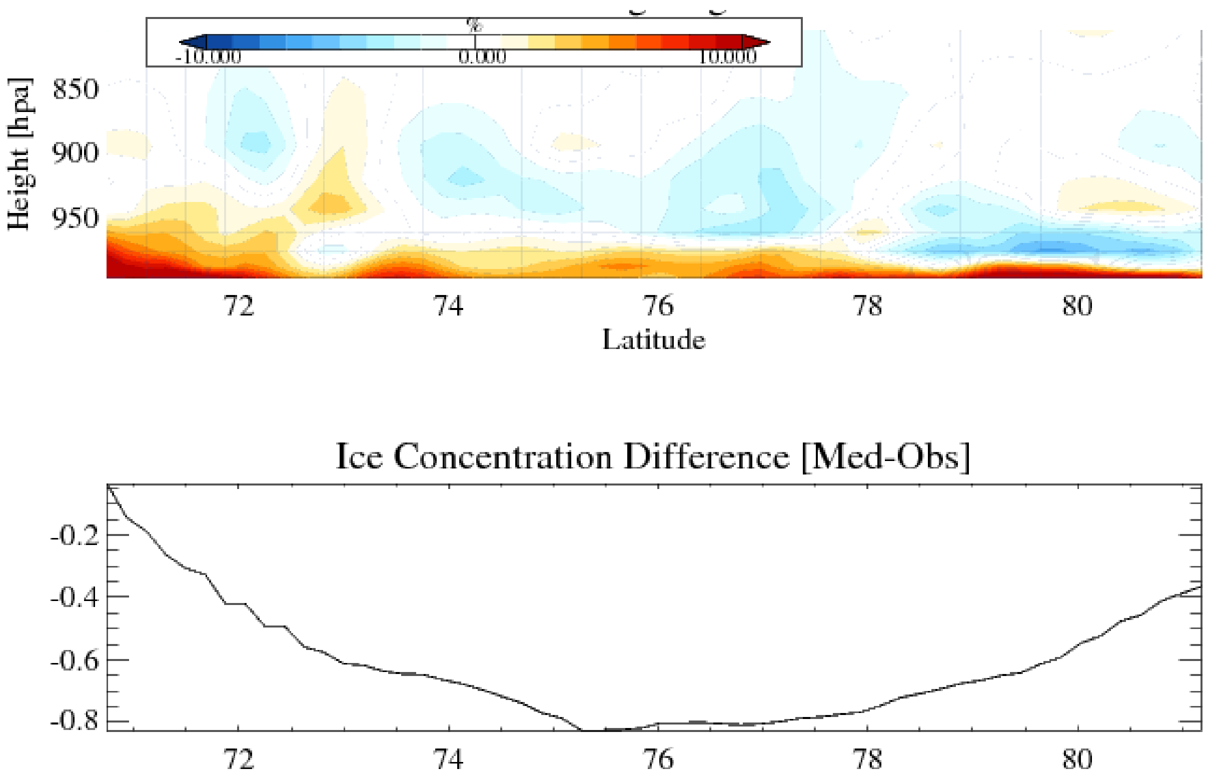

Figure 4 a) Cross section (along -150W longitude) of modeled wind speed change (in %) averaged over July and August using 2012 sea ice conditions or sea ice conditions based on the 1979-2011 median (actual – median) b) Sea ice concentration difference (actual - median). Sea ice concentration and thickness for both scenarios were specified from the PIOMAS ice-ocean data assimilation system.

Figure 4 demonstrates a potentially important impact of sea ice loss on the overlying atmosphere. The model scenario which uses actual 2012 sea ice conditions shows increased near-surface wind speeds over areas where sea ice has been lost. This acceleration of wind speeds is likely due to decreases in atmospheric static stability at lower levels. This mechanism may constitute an important feedback on sea ice dynamics that will impact the evolution of sea ice cover.

IMPACT/APPLICATIONS

These preliminary results underline the importance of accurate SST retrievals as a critical requirement for atmospheric modeling experiments. Currently available satellite SST products appear to be biased and display spurious variability when compared to in-situ data.

The impact of sea ice loss on the atmosphere and potential feedbacks on sea ice dynamics via increased wind speeds needs to be considered in modeling and forecasting the evolution of the atmosphere-ice-ocean dynamics of the seasonal sea ice zone.

RELATED PROJECTS

Zhang (PI) MIZMAS: Modeling the Evolution of Ice Thickness and Floe Size Distributions in the Marginal Ice Zone of the Chukchi and Beaufort Sea (ONR, MIZ DRI)

Morison (PI) Ocean Profile Measurements During the SIZRS (ONR Core)

Steele (PI). UptempO buoys for understanding and prediction (ONR-Core)

Lindsay (PI). Visible and Thermal Images of Sea Ice and Open Water from the Coast Guard Arctic Domain Awareness Flights (ONR-Core)

Rigor (PI). International Arctic Buoy Program (ONR-Core)

Morision (PI). SIZRS Coordination (ONR-Core)

PUBLICATIONS

Helene Hewitt, S. B., Danny Feltham, Chris Folland, Katharine Giles, Tim Graham, Ed Hawkins, Dan Hodson, Laura Jackson, Sarah Keeley, Ann Keen, Seymour Laxon, Alison McLaren, Matt Menary, Matt Palmer, Jeff Ridley, Adam Scaife, Doug Smith, Meric Srokosz, Alex West, Richard Wood, Axel Schweiger (2012), Assessment of Possibility and Impact of Rapid Climate Change in the Arctic *Rep.*, 62 pp, UK MetOffice, Hadley Centre